Towards an integrated taxonomy of the *Merodon equestris* species complex (Diptera: Syrphidae) including description of a new species, with additional data on Iberian *Merodon*

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Abstract—Study of specimens of *Merodon* Meigen collected in southwestern Europe resulted in new data and taxonomic changes for this genus. The cryptic species *Merodon confusus* **sp. nov.** (*Merodon equestris* species group) is described based on specimens collected in Cabañeros National Park, central Spain. Morphological and molecular diagnostic characters are provided to separate members of the species group. *Merodon aeneus fulvus* Gil Collado is proposed as a junior synonym of *Merodon pumilus* Macquart. The first Iberian record of *Merodon rufus* Meigen is reported and updates of the revision of Iberian *Merodon* are provided.

Résumé—L'étude de spécimens de *Merodon* Meigen collectés dans le sud-ouest de l'Europe, a conduit à de nouvelles données et modifications taxonomiques pour ce genre. L'espèce cryptique *Merodon confusus* **sp. nov.** (groupe *Merodon equestris*) est décrite à partir de spécimens attrapés dans le Parc National Cabañeros, au centre de l'Espagne. Les caractères morphologiques et moléculaires de diagnostique sont fournis afin de séparer *Merodon confusus* des autres espèces du groupe. *Merodon aeneus fulvus* Gil Collado est proposée comme synonyme de *Merodon pumilus* Macquart. Il s'agit de la première mention de *Merodon rufus* Meigen dans la Péninsule Ibérique, et une mise à jour de la révision publiée des espèces de *Merodon* dans la Péninsule Ibérique est fournie.

Introduction

Merodon Meigen (Diptera: Syrphidae) is the second largest hoverfly genus in Europe (Speight 2010), and the most species-rich genus in the European Mediterranean region. It is distributed throughout the Palaearctic and Ethiopic regions with highest species diversity in Eastern Europe and Asia Minor (A. Vujić, S. Radenković, and J. Acanski, unpublished data). Adults mimic bees and bumble bees (Hymenoptera: Apidae) and feed on pollen and nectar from early spring to autumn (Hurkmans 1993; Speight 2010). Larvae are phytophagous, tunnelling inside bulbs or rhizomes of monocotyledonous plants (Hurkmans 1993; Ricarte *et al.* 2008).

Merodon equestris (F.), the "large narcissus fly", is well-known because of damage that larvae cause to daffodil (*Narcissus* L. (Liliaceae) and other ornamental bulbs in Europe and elsewhere (Conijn 1990; Barkemeyer 1994; Speight 2010). Adult *M. equestris* show high morphological variability expressed as several distinctive colour morphs. Other species of *Merodon* also show intraspecific morphological variability, for example, in characters such as the anterior

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lobe of the surstylus in male genitalia (Popov 2000).

A revision of Iberian species of *Merodon* (Marcos-García *et al.* 2007) described intraspecific variability in nine species in different species groups. Morphological variability may hide cryptic species, as has been demonstrated using DNA sequences of the mitochondrial cytochrome *c* oxidase subunit I (COI) gene (Ståhls *et al.* 2009; Radenković *et al.* 2011). Some Iberian specimens of *M. equestris* cannot be identified readily using external morphological characters in the keys and descriptions presented by Marcos-García *et al.* (2007), suggesting the existence of a species complex within *M. equestris*.

Molecular data are useful for solving species level taxonomic problems. Through allozyme electrophoresis and mitochondrial DNA sequencing of COI, six diagnosable cryptic taxa have been identified within the *Merodon aureus* F. and *Merodon cinereus* (F.) species complexes (Milankov *et al.* 2008). Moreover, an integrative taxonomic approach using morphological and molecular characters was informative for discerning *Merodon* species groups and detecting cryptic species in the Iberian Peninsula (Mengual *et al.* 2006). Also, COI barcodes generated for 22 species of *Merodon* species from Lesvos Island (Greece) revealed two cases of morphologically cryptic species (Ståhls *et al.* 2009; Radenković *et al.* 2011). An integrative taxonomy approach has also revealed the existence of new species of *Merodon* species in southeastern Europe (A. Vujić, S. Radenković, G. Ståhls, and J. Acanski, unpublished data).

To analyse the status of morphologically atypical specimens of *M. equestris*, we used an integrated approach based on both morphology and genetics. Our work has resulted in new data on the Iberian *Merodon* fauna and has allowed various refinements to the revision of Iberian species of *Merodon* in Marcos-García *et al.* (2007).

Material and methods

Material examined

We examined specimens of *Merodon* collected in Finland, France, Italy, Portugal, and Spain (Fig. 1). Specimens determined to be *Merodon confusus* **sp. nov.** were collected at various French, Portuguese, and Spanish localities by hand net, Malaise traps, and occasionally yellow pan traps. Specimen label dates indicate capture technique: hand netting is indicated by a single date (*e.g.*, 16.iv.2004) with localities coded as "Ma2" and "Pa1"; a date interval (*e.g.*, 28.iii/15.iv.2004) indicates Malaise ("ma" followed by "F", "M", or "J" and "1" or "2") or yellow pan trapping ("moF2"). Trapped specimens were preserved in ethanol and then dried and mounted on entomological pins.

Geographical distribution data follow Speight (2010). Biological and specimen deposition data are provided for each species. If deposition is not stated, material is in the Colección Entomológica Universidad de Alicante (CEUA), Spain. Collection acronyms are ASC, Dr. Axel Ssymank; IEE, former Instituto Español de Entomología, collection now in Museo Nacional de Ciencias Naturales, Madrid, Spain (MNCN); MZH, Finnish Museum of Natural History, Helsinki, Finland; NS, Department of Biology and Ecology, Entomological Collection, University of Novi Sad, Serbia; ZMUC, Zoological Museum, University of Copenhagen, Denmark; and ZMA, Zoological Museum Amsterdam, University of Amsterdam, the Netherlands.

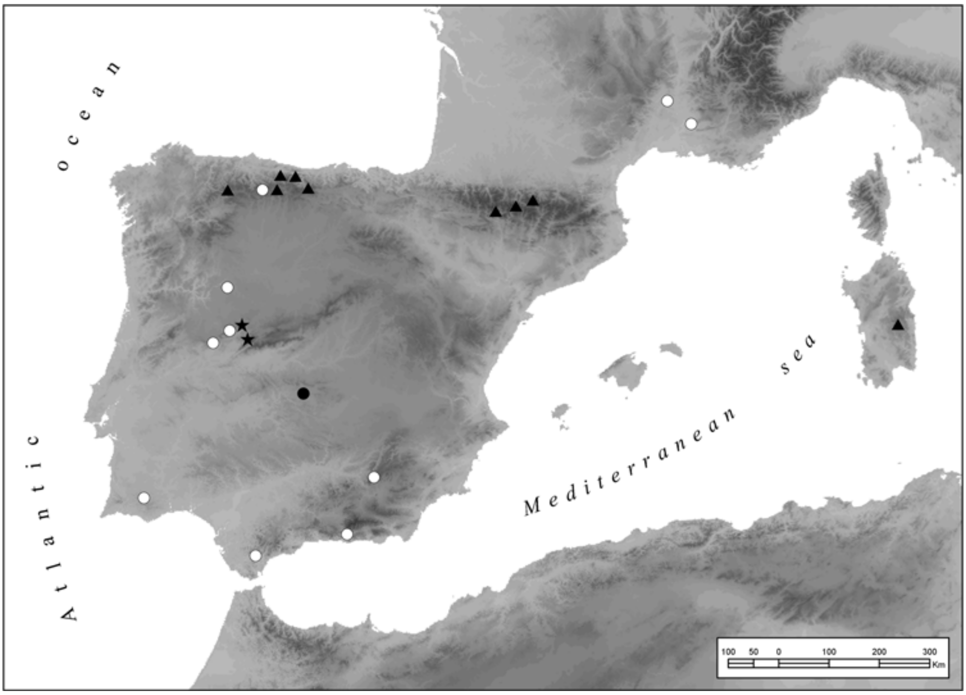
Refinements to the key in Marcos-García *et al.* (2007) were made to enable the identification of species of *Merodon* recently recorded in the Iberian Peninsula (Ricarte and Marcos-García 2008), as well as species newly described or recorded in this study.

Morphological study

A detailed description and diagnosis for *M. confusus*, as well as figures of various adult characters of this and other species of *Merodon* are provided.

Colour characteristics are described from dry-mounted specimens. To study the male genitalia, dry specimens were relaxed and genitalia were dissected with an entomological pin. Genitalia were cleared by boiling individually in tubes of water-diluted KOH pellets for 5–7 min. This was followed by brief immersion in acetic acid to neutralize the KOH, immersion in ethanol to remove the acid,

Fig. 1. Map of southwestern Europe showing the distribution of the examined specimens. ●, type material locality: *Merodon confusus* specimens genetically tested; ○, additional material locality: *M. confusus* specimens morphologically fitting the type material but not genetically tested except for one specimen from Spain (S478, see text); ▲, *M. equestris* locality: no Iberian specimen was genetically tested except for a specimen from the Pyrenees (in addition to a specimen from Sardinia); ★, locality of specimens of uncertain status: morphology intermediate between *M. confusus* and *M. equestris*.



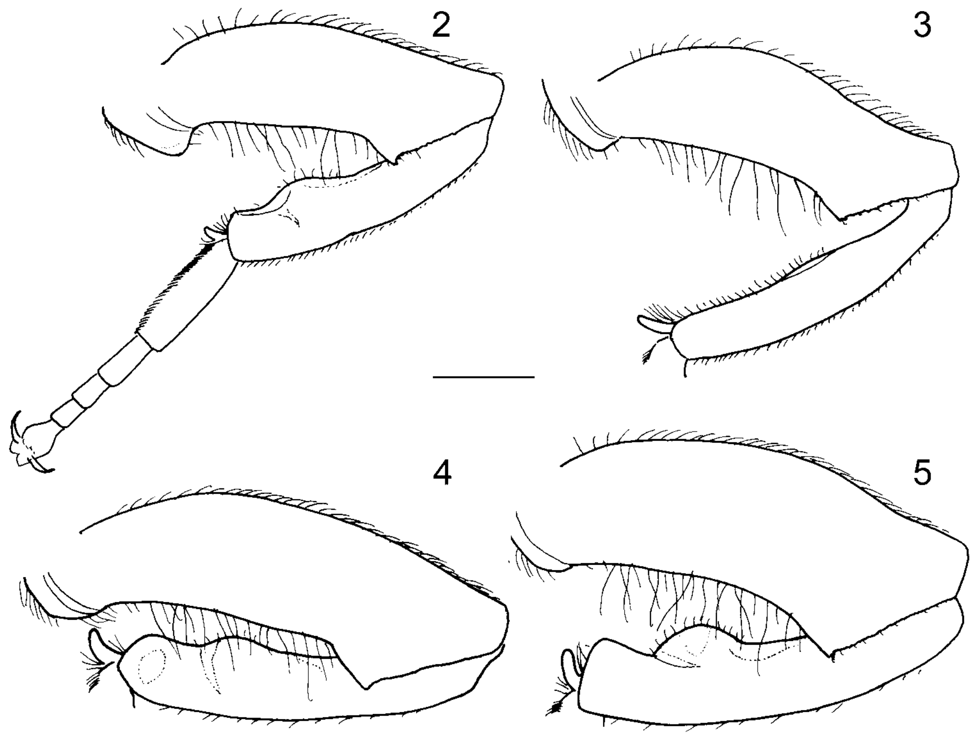
and storage in microvials containing glycerine. Drawings were made with a FSA 25 PE drawing tube attached to a binocular dissecting microscope. Measurements were taken with an eyepiece graticule. The following abbreviations are used in the new species description: bc, relation between the basal line of cercus and its height; bf, relation between the distance from the basoflagellomere apex at the most prominent point of the pedicel and the basoflagellomere width at the level of the arista base; C, second costal cell; R1, cell R1; Sc, subcostal vein (for more details see figures in Marcos-García *et al.* 2007). Morphological terminology broadly follows Thompson (1999), except for male genitalia, which follows Hurkmans (1993) and Doczkal (1996).

Molecular study

Six adult specimens from Cabañeros National Park, central Spain (39°23′47″N, 4°29′14″W), representing part of the type material for the new species, were used for molecular analysis. Additionally, DNA sequences for a specimen of the new species from Andalucía, seven specimens of *M. equestris*, and a specimen of an undetermined species similar to it ("*M.* aff. *equestris*") from south and north Europe were included for comparison of levels of intra- and interspecific genetic divergences of the mitochondrial COI sequences.

DNA was extracted from two legs of each fly (sometimes also including part of the abdomen) using the Nucleospin Tissue DNA extraction kit (Machery-Nagel, Düren, Germany) following the manufacturer's protocols and re-suspended in 50 μL of ultrapure water. The "small barcode fragment" of the 5′ region of COI was amplified using standard polymerase chain reaction protocols (annealing temperature 49 °C) with forward primer C1-S-1718 (5′-GGAGGATTTGGAATTGATTAGTTCC-3′) (Simon *et al.*

Figs. 2–5. Hind legs of male *Merodon*. 2, *M. confusus*; 3, *M. flavus*; 4, *M. confusus*/*M. equestris* (specimen morphologically intermediate); 5, *M. equestris*. Scale bar = 0.5 mm.



1994) and reverse primer HCO-2198 (5′-TAAACTTCAGGGTGACCAAAAAATCA-3′) (Folmer *et al.* 1994). The fragments were sequenced using the same primers and the Big Dye Terminator version 1.1 cycle sequencing kit (Applied Biosystems, Foster City, California). With these primers, we obtained an almost completely overlapping sequence fragment of approximately 450 bp. All sequences were submitted to EMBL (EMBL accession Nos. FR717714-27). Alignment of COI sequences was trivial due to a lack of insertions or deletions and was determined visually. *Merodon albifrons* Meigen (tribe Eumerini) was used as an outgroup. The COI sequences were clustered using parsimony analysis performed with NONA (Goloboff 1999) spawned with the aid of Winclada (Nixon 2002), using the heuristic search algorithm with 1000 random addition replicates (mult × 1000), holding 100 trees per round (hold/100), maxtrees set to 100 000 and applying treebisection–reconnection branch swapping. Subsequently the Bremer support values (Bremer 1988, 1994) were calculated by successively increasing the number of trees held at each step for finding suboptimal trees to avoid an over estimation of the values. All base positions were treated as equally weighted characters (Kimura 1980).

Results

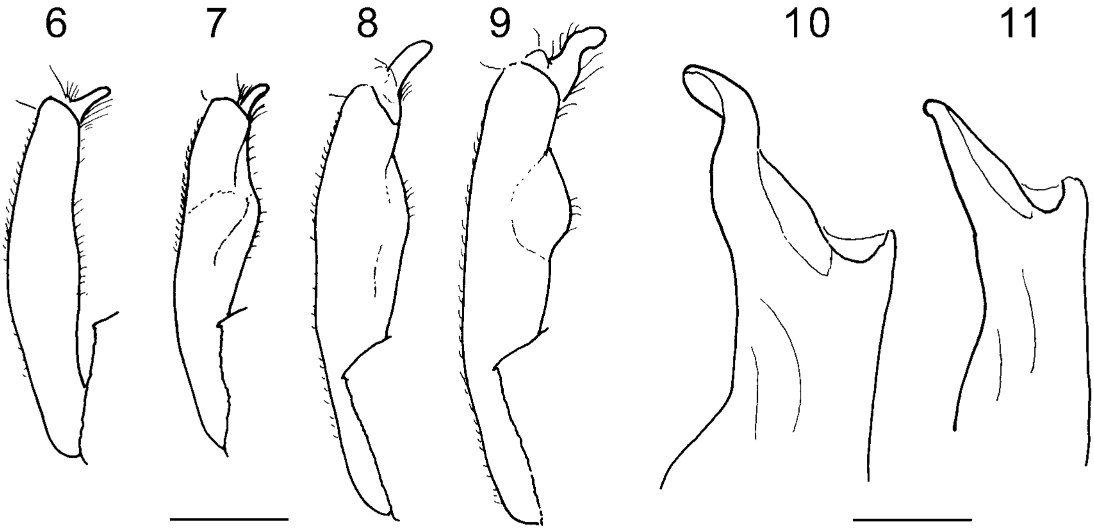
As a result of the present study, we describe a new cryptic species, *M. confusus*, belonging to the *M. equestris* group of species. Additionally, we report the first record of *Merodon rufus* Meigen from the Iberian Peninsula and propose *Merodon aeneus fulvus* Gil Collado as a new junior synonym of *Merodon pumilus* Macquart. Changes derived from these new data are provided for the key in the revision of the Iberian species of *Merodon* in Marcos-García *et al.* (2007).

Genus *Merodon* Meigen, 1803

Merodon confusus sp. nov.

(Figs. 1–2, 7, 11–15, 23–27, 32–33, 38–42)

Figs. 6–11. Hind tibia (left) and detail of its apical process (right) of male *Merodon*. 6, *M. flavus*; 7, 11, *M. confusus*; 8, *M. confusus*/*M. equestris* (specimen morphologically intermediate); 9, 10, *M. equestris*. Left scale bar = 1 mm; right scale bar = 0.5 mm.



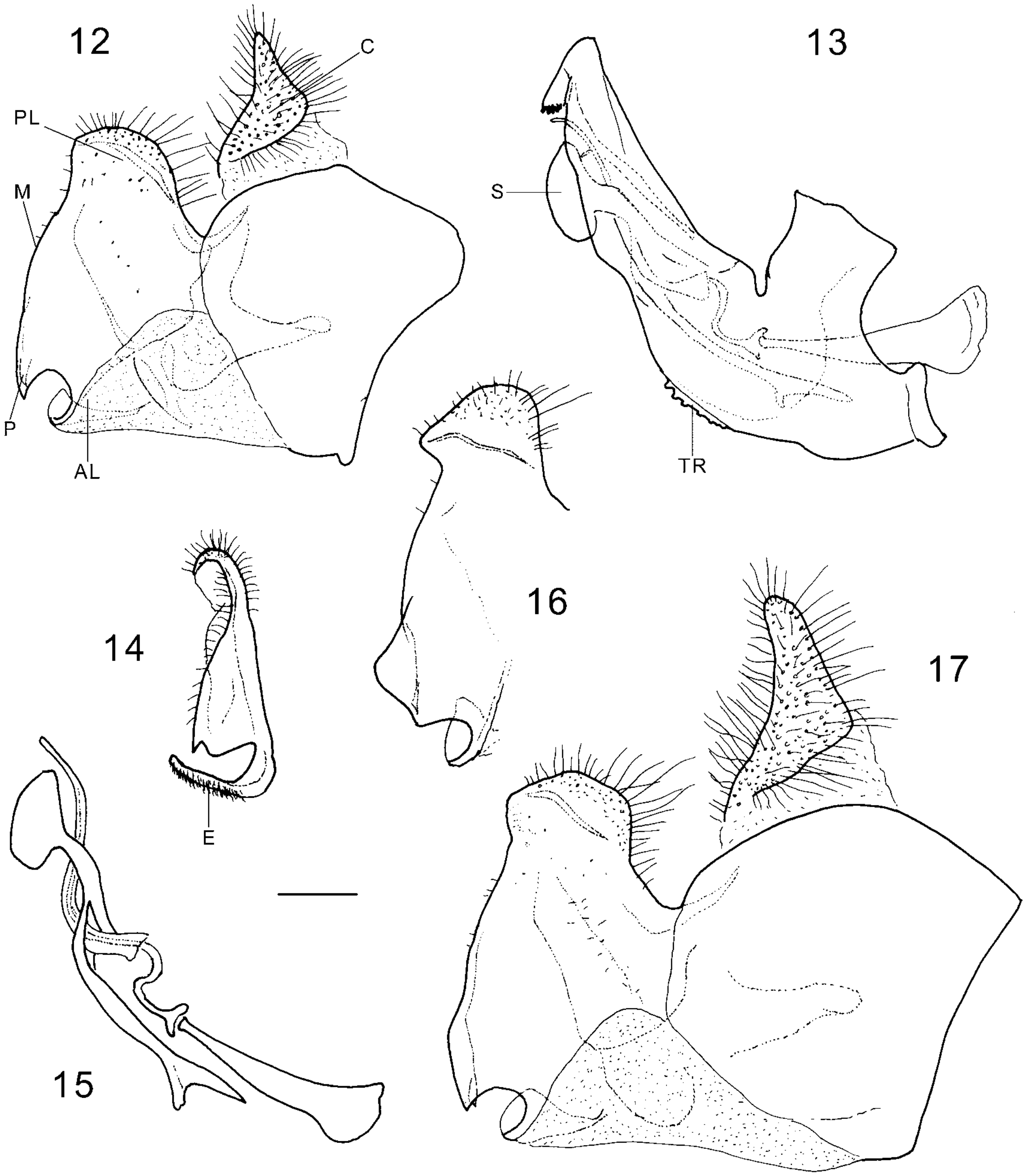
Type material (Fig. 1, black circle)

Holotype: SPAIN, Ciudad Real: 1♂, P.N. de Cabañeros, Ma2, 20.v.2005, Leg. A. Ricarte (Fig. 45, code 4738; EMBL accession number FR717721). *Paratypes*: SPAIN, Ciudad Real: 3♂, P.N. de Cabañeros, Ma2, 20.v.2005, Leg. A. Ricarte (two specimens for DNA analysis, Fig. 45, codes 4740 and 4744; EMBL accession numbers FR717722-23); 3♂, P.N. de Cabañeros, Pa1, 1.v.2005, Leg. A. Ricarte (Fig. 45, codes 4722, 4723 and 4725; EMBL accession numbers FR717718-20); 1♂, P.N. de Cabañeros, camino Valle de Santiago, 16.iv.2004, Leg. E. Galante (NS); 2♀, P.N. de Cabañeros, Pa1, 14.iv.2004, Leg. A. Ricarte (one female deposited in NS); 2♀ and 2♂, P.N. de Cabañeros, maF2, 28.iii–15.iv.2004, Leg. A. Ricarte; 2♀, P.N. de Cabañeros, moF2, 28.iii–15.iv.2004, Leg. A. Ricarte; 1♀ and 1♂, P.N. de Cabañeros, maM2, 26.iii/14.iv.2004, Leg. A. Ricarte; 1♂, P.N. de Cabañeros, camino Valle de Santiago, 14.v.2004, Leg. A. Ricarte; 2♂, P.N. de Cabañeros, camino Valle de Santiago, 14.iv.2004, Leg. A. Ricarte (one male deposited in NS); 2♂, P.N. de Cabañeros, maM1, 14.iv–8.v.2004, Leg. A. Ricarte; 1♀, P.N. de Cabañeros, maM2, 14.iv–8.v.2004, Leg. A. Ricarte; 3♀ and 1♂, P.N. de Cabañeros, maF2, 15.iv–7.v.2004, Leg. A. Ricarte; 2♀, P.N. de Cabañeros, maM1, 26.iii–14.iv.2004, Leg. A. Ricarte (one female deposited in NS); 1♀, P.N. de Cabañeros, maF1, 15.iv–7.v.2004, Leg. A. Ricarte; 1♀ and 1♂, P.N. de Cabañeros, maJ2, 18.iii–12.iv.2005, Leg. A. Ricarte; 2♀ and 4♂, P.N. de Cabañeros, maF1, 19.iii–13.iv.2005, Leg. A. Ricarte (1♀ and 1♂ deposited in MNCN); 1♀, P.N. de Cabañeros, maF2, 19.iii–13.iv.2005, Leg. A. Ricarte. All males with genitalia in a plastic micro-vial attached to the pin.

Additional material (Fig. 1, white circles)

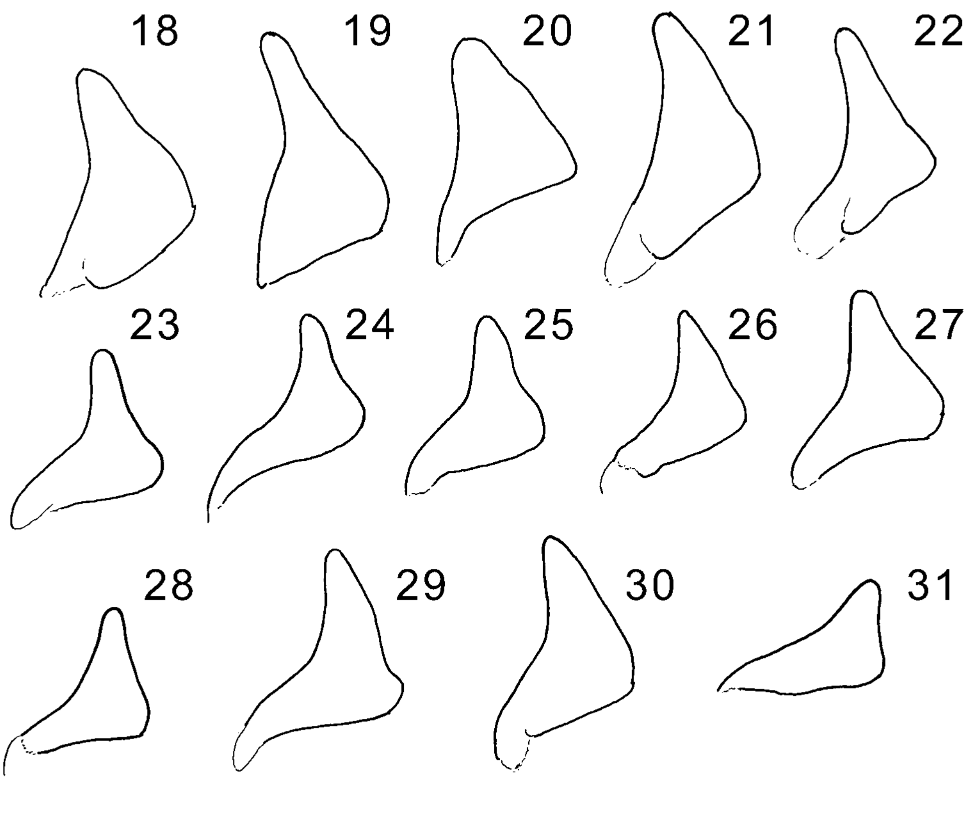
Non-Cabañeros specimens morphologically fitting to the type material of *M. confusus* but not genetically tested (genetic analysis was not performed because of the age of material) except for one specimen*. FRANCE: Dep. 07, 1♂, Ardèche, St. Remèze, 2.v.1981, Leg. R. Leys (NS); VSE, 1♂, Mt du Lubéron, W de Bonnieux, 350–600 m, 3.vi.1995, Leg. Merz & Eggenberger (ZMA). PORTUGAL: Algarve, 1♂, Doguena, 16.iv.1983, H.Teunissen (ZMA). SPAIN: Cáceres: 2♂, Gata, 19.iv.1981, Leg. M.ªA. Marcos; León: 1♂, Cofiñal, 16.vi.1986, Leg. M.ªA. Marcos-García; Cádiz: 1♂, Vent. l. Canillas, Hozgarganta-Talb. Jimena, 250 m, 14.iv.1985, Leg. W. Schacht; Granada: 1♂,

Figs. 12–17. Genitalia of male *Merodon*. 12–15: *M. confusus*; 12, epandrium, lateral view; 13, hypandrium, lateral view; 14, left surstylus, anterior view; 15, aedeagus and annex structures, lateral view; 16, *M. flavus*, left surstylus, lateral view; 17, *M. equestris*, epandrium, lateral view. AL, anterior surstylar lobe; C, cercus; E, extension of anterior surstylar lobe; P, prominence of the anterior surstylar lobe; PL, posterior surstylar lobe; M, surstylus margin; S, lateral sclerite of aedeagus; TR, thecal ridge. Scale bar = 0.25 mm.



Barranco de Miranda, 450 m, 6.iv.1974, Leg. J.A.W. Lucas; Salamanca: 1♂, Almendra, 28.iii.1982, Leg. L.J. García; 1♂, Valle Batuecas (Monasterio), 11.v.1980, Leg. M.A. Marcos. *SPAIN: Andalucía (Jaén), 1♀, Sierra Pozo, 1450 m, Mnt. Palomas, 11.vi.2003, Leg. M. Kafka (DNA voucher specimen, S478-2004, G. Ståhls, FMNH, Helsinki, Finland, EMBL

Figs. 18–31. Range of variability of cercus in genitalia of male *Merodon*, lateral view. 18–22, *M. equestris*; 23–27, *M. confusus*. (type material); 28–30, *M. confusus*/*M. equestris* (specimens morphologically intermediate); 31, *M. flavus*. Scale bar = 0.25 mm.



accession no FR717714) (MZH). This specimen, morphologically fitting to *M. confusus*, was genetically tested. Analysis results showed a higher pairwise divergence between this specimen and the population from Cabañeros (five nucleotides difference) than among specimens from Cabañeros (Table 2). We consider this divergence to be within the range of intraspecific variability in *M. confusus*.

Etymology

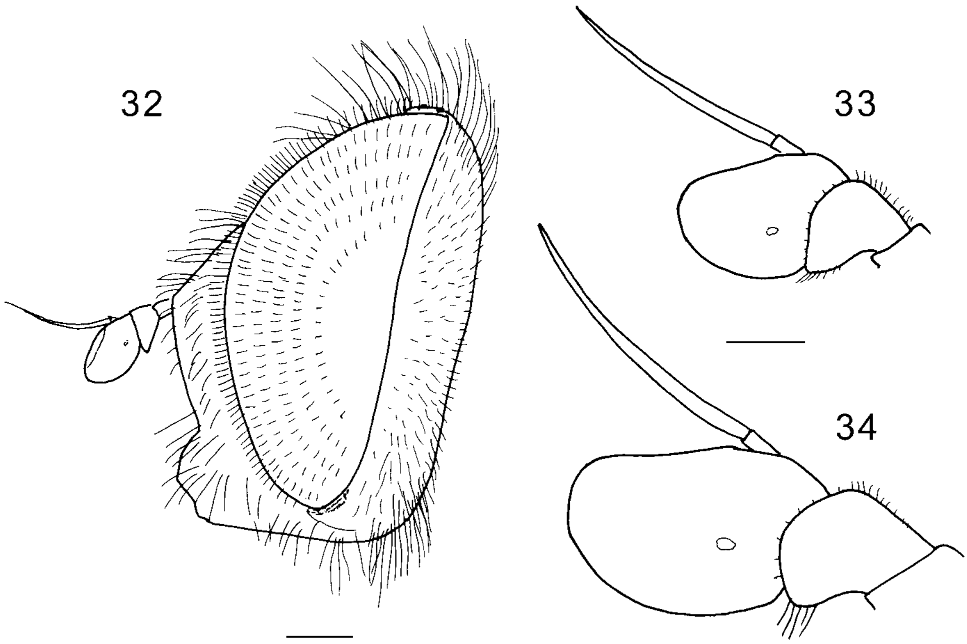
The word "confusus" means "mixed" in Latin. This term is employed to refer to the combination of characters of typical *M. equestris* and *Merodon flavus* Sack in the new species.

Diagnosis

The species belongs to the *M. equestris* group, comprised of large adults (8–17 mm) with hairy posterior side of mid-coxa and reduced pilosity on anterior anepisternum below postpronotum (Marcos-García *et al.* 2007). *Merodon confusus* is a bumble bee mimic with long body hairs; male hind tibia with a conspicuous apical process (Figs. 2, 7, 11); male genitalia with anterior surstylar lobe curved internally (Fig. 14); lateral sclerite of aedeagus oval apically (Figs. 13, 15); cercus triangular-shaped (Figs. 12, 23–27).

Merodon confusus is very similar to *M. equestris* and *M. flavus*. Adult *M. confusus* (10–12.5 mm) are typically smaller than adult *M. equestris* (13–17 mm). Males: apical process of hind tibia short and not strongly incurved in *M. confusus* (Fig. 11), longer and conspicuously incurved in *M. equestris* (Fig. 10); cercal triangle higher in *M. equestris* (bc = 0.66–0.96) (Figs. 18–22) than in *M. confusus* (bc = 1–1.23) (Figs. 23–27); *M. confusus* with a conspicuous central bulge on the hind

Figs. 32–34. Head, lateral view, and right antenna, inner view, of female *Merodon*. 32, 33, *M. confusus*; 34, *M. equestris*. Head scale bar = 0.5 mm, antenna scale bar = 0.25 mm.



tibia (Figs. 2, 7), lacking in *M. flavus* (Figs. 3, 6); margin of the anterior surstylar lobe flat in *M. confusus* (Fig. 14), convex in *M. flavus* (Fig. 16); cercus as long as high or slightly longer in *M. confusus* (bc = 1–1.23) (Figs. 23–27), conspicuously longer (up to 1.5 × longer than high) in *M. flavus* (bc = 1.11–1.47) (Fig. 31). Females: basoflagellomere in *M. confusus* shorter (bf = 1.1) than that in *M. equestris* (bf = 1.3); *M. confusus* has long hairs on ventral side of hind femur (hairs as long as femur width) (Fig. 42) and long semi-adpressed and erect hairs on tergites III and IV, *M. flavus* has shorter hairs on ventral side of hind femur and hairs on tergites III and IV are mostly adpressed (with a few intermixed erect hairs).

Morphological species boundaries within the *M. equestris* group are partially unclear. Overlapping characters for *M. confusus* and *M. equestris* are: in males, cercus shape, body size, apical process of hind tibiae, central bulge in hind tibiae, and colour morphs. *Merodon flavus* can be separated morphologically; molecular confirmation is needed to distinguish *M. confusus* from *M. equestris* when morphology is not definitive.

Merodon confusus and *M. equestris* differ by an uncorrected pairwise genetic difference of 1.96%–3.69% for the COI barcode (Table 2); this is a typical percentage range of species level difference for closely related species of *Merodon* (*e.g.*, Mengual *et al.* 2006; Ståhls *et al.* 2009).

Table 1 shows variability ranges of body size, bc and bf for the studied taxa and populations; Table 2 shows the uncorrected pairwise percent divergences.

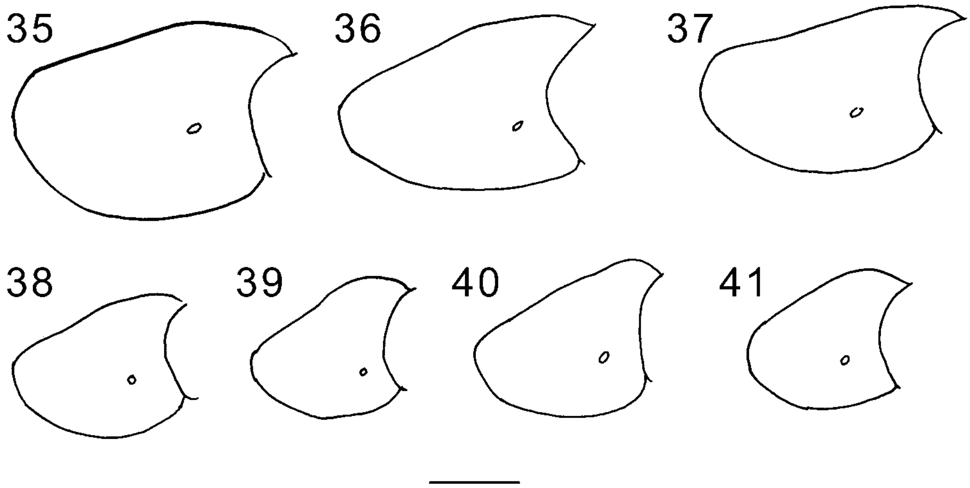
Male

(Figs. 2, 7, 11–15, 23–27)

Head

Dark antenna; basoflagellomere 1.3 × longer than broad, with dorsal margin concave and apex acute; arista brown basally, dark brown towards apex, and 1.6 × longer than basoflagellomere; face and frons shiny black, covered with whitish-yellow hairs and silver-grey pollinosity; oral margin bare, lustrous black; vertical triangle isosceles, 2–2.5 × longer than eye contiguity, black with yellowish pollinosity, covered

Figs. 35–41. Basoflagellomere, right antenna, inner view, of female *Merodon*. 35, 36, *M. equestris*; 37, *M. flavus*; 38–41, *M. confusus*. Scale bar = 0.25 mm.

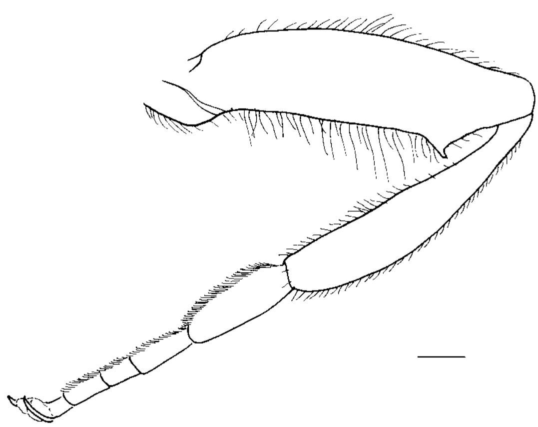


with long yellow hairs, and, occasionally, with a few black hairs intermixed with yellow hairs on ocellar triangle; eye contiguity long for 10–12 facets; ocellar triangle isosceles; eye hairs whitish-yellow, about as long as scape; occiput covered with dense whitish pollinosity and yellowish hairs.

Thorax

Mesonotum with dark-gold metallic reflections, covered with erect yellow to reddish-yellow hairs and, in some morphs, partly covered with black hairs; two colour morphs have been identified: one completely yellow-haired, another with black hairs on posterior half of scutellum and yellow hairs on some parts of postalar callus; posterior anepisternum, anepimeron, and katepisternum dorsally with long whitish yellow hairs; pale-greyish wing, extensively microtrichose except for some areas along sides of veins in the central part of wing; wing veins dark except basally and on most of length C, Sc and R1; dorsal and ventral calypters light brown; halter brownish; legs with tarsi brown to reddish-brown except black ventrally; hind trochanter with gently produced process (Fig. 2); hind tibia with a conspicuous central bulge ventrally (Figs. 2, 7) and apical process pointing forwards (Figs. 2, 7, 11); legs with black and yellow hairs; short hairs on legs

Fig. 42. Hind leg of female *Merodon confusus*. Scale bar = 0.5 mm.

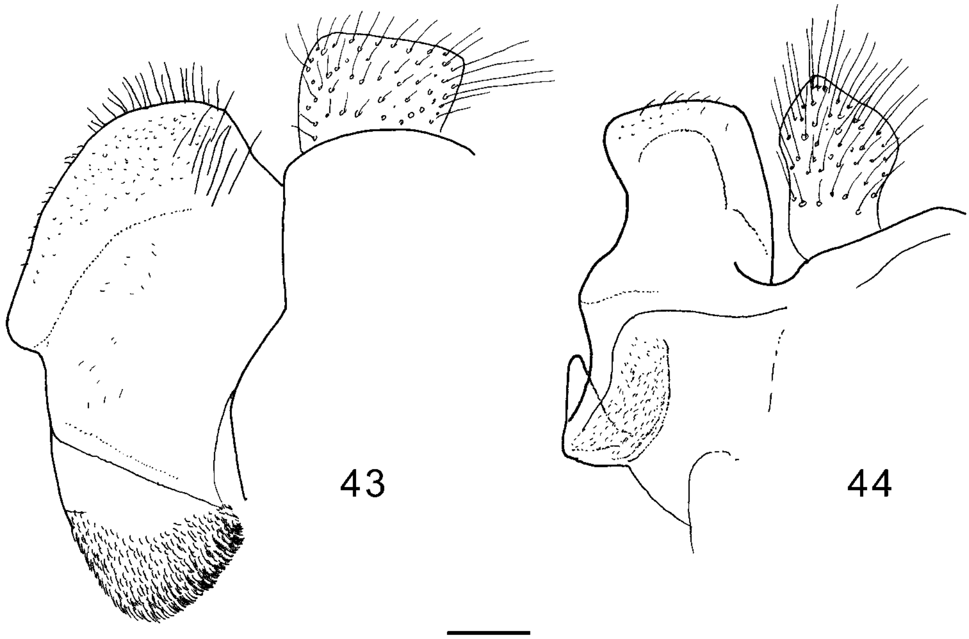


predominately black, long hairs on femur ranging from mostly yellow to mostly black.

Abdomen

Black with bronze reflections, as long as mesonotum; tergites II–IV shiny, without bands of white pollinosity; tergite II with yellowish anterolateral spots; hairs on terga erect and yellow to reddish-yellow; tergites III and IV sometimes with black hairs in different locations; sterna shiny, blackish-brown, with long light yellow hairs.

Figs. 43–44. Genitalia of male *Merodon*. 43, *M. distinctus*: left surstylus and cercus, lateral view; 44, *M. rufus*: left surstylus and cercus, lateral view. Scale bar = 0.25 mm.



Genitalia

Posterior surstylar lobe rounded (Fig. 12); surstylus margin convex; anterior surstylar lobe with conspicuous prominences (Fig. 12); cercus triangular (Figs. 12, 23–27); hypandrium with folded thecal ridge (Fig. 13); lateral sclerite of aedeagus rounded apically (Fig. 13).

Female

(Figs. 32, 33, 38–42)

Similar to male except for characters associated with typical sexual dimorphism. Key characters for female *M. confusus*: frons black with shiny central stripe, greyish pollinosity laterally; frons from completely pale haired to bearing many black hairs on central stripe; ocellar triangle always surrounded by black hairs; colour of scutellar hairs in two morphs similar to those in males; hind legs without conspicuous tubercles and prominences (Fig. 42); abdomen with pale and black hairs: tergites I and II pale-haired; tergites III–V with pale and black hairs intermixed and ranging from mostly pale to mostly black; sternites IV and V sometimes with a few black hairs.

Biology

The type material was collected in the following habitats: open areas with *Fraxinus angustifolia* Vahl (Oleaceae) and seasonal streams; *Quercus pyrenaica* Willd. (Fagaceae) forests; mixed forests of *Q. pyrenaica* and *F. angustifolia*; high Mediterranean scrubs; tracks and track verges in Mediterranean forests and scrubs. Period of flight: from March to June.

Distribution

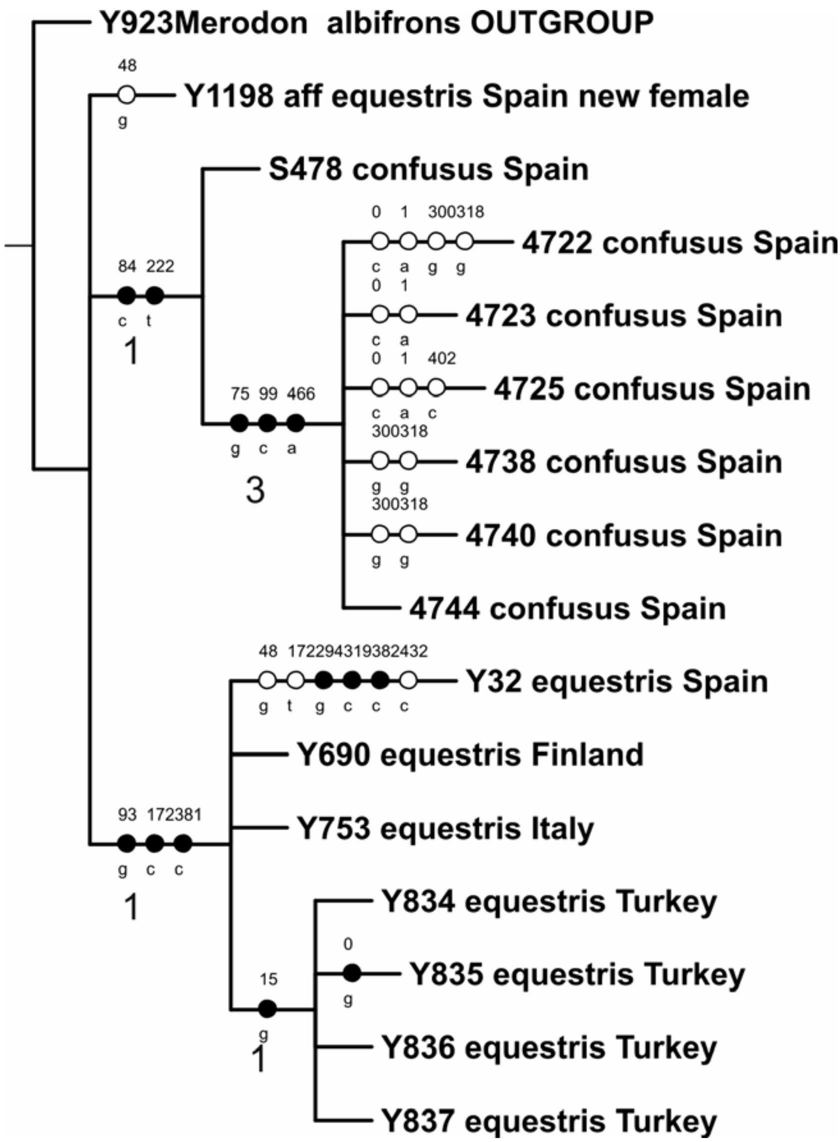
Spain (Fig. 1). The species presumably extends to Portugal and France, where specimens with the same morphology have been found but were not molecularly analyzed.

Additional data for Iberian *Merodon*

Material examined belonging to *M. equestris* (Fig. 1, black triangle)

Spanish specimens diagnosed morphologically (genetic analysis not performed because of age of material). SPAIN, Asturias: 1♂, Santillán, 6.vii.1986, Leg.: M.A. Marcos-García; 1♂, Tielve, 21.vi.1987, Leg.: M.A. Marcos-García;

Fig. 45. Parsimony analysis of COI sequences of species of *Merodon*. Strict consensus of 48 equally parsimonious trees, L = 51 steps, CI = 0.84, RI = 0.88. Open circles denote homoplasious characters and filled circles denote non-homoplasious characters. Bremer support values are indicated below branches.



Huesca: 1♂, Baños de Benasque, 12.viii.1991, Leg.: M.A. Marcos-García; 1♂, Valle de Añisclo, 15.vii.1981, Leg. E. Galante; León: 2♂, Caboalles de Abajo, 2.vi.1987, Leg.: M.A. Marcos-García; Lérida: 1♀, Bosque de Bonabé, Vall d'Arán, 4.vii.1997, Leg. Verdú; 1♀ and 1♂, Cofiñal, 3.vii.1987, Leg.: M.A. Marcos-García; Palencia: 1♀ and 1♂, Piedrasluengas, 1280 m, prado junto al río en hayedo, 21.vii.1985, Leg.: M.A. Marcos.

Specimens with COI barcodes from other localities: FINLAND: 1♀, Nylandia (N), Askola, emerged from *Allium* L. (Liliaceae) kept indoors 12.i.2007 (MZH); labcode MZH_Y690, EMBL accession number EU431486. ITALY: 1♀, Sardinia, Nuoro province: nr Aritzo, ca 1000 m, 23.v.2008, Leg. E. Rättel (MZH); labcode MZH_Y753 (this is the only non-Iberian specimen of *M. equestris* from a locality represented in Fig. 1, EMBL accession number FR717716);

SPAIN: 1♂, Pyrenees, Aran Valley, nr. Arties, 1500 m, 1.viii.2003, G. Ståhls leg. (MZH); labcode MZH_Y32, EMBL accession number FR717715 (this is the only Spanish specimen diagnosed with morphological and genetic evidence; its locality nearly coincides with the most eastern black triangle in the Pyrenees in Fig. 1); FRANCE: 1♂, Jura mountains, Les Moulines, Cariche, 1290 m, 19.VII.2008, A. Ssymank leg. (ASC); labcode MZH_Y834. Also samples MZH_Y835, MZH_Y836, and MZH_Y837 (Fig. 45) from France, Jura mountains, Lajoux, Forêt du Massacre, 1270 m, 19.VII.2008, A. Ssymank leg, (ASC), EMBL accession numbers FR717724-27.

Material examined of uncertain status (Fig. 1, black star)

Specimens morphologically intermediate between *M. confusus* and *M. equestris* (genetic analysis not performed because of age of material). SPAIN, Cáceres: 1♂, La Garganta, 5.vi.1983, Leg. H. Teunissen; Salamanca: 1♂, La Honfría, 12.vi.1990, Leg. M.A. Marcos-García. A female of uncertain status (reared from larva collected from a bulb in Spain, Salamanca, Sierra de Béjar, 19.iii.2010 by M.A. Marcos-García) was used for DNA analysis (Fig. 45, labcode MZH_Y1198; EMBL accession no FR717717). This specimen is morphologically and genetically different from *M. equestris* and *M. confusus*. Because of the proximity and similarity of the collection localities of this female and the La Garganta and La Honfría males, and their apparently related morphology, we hypothesize that they could belong to another cryptic new taxon. Resolution of this issue requires the collection and study of additional material.

First records of *M. rufus* Meigen, 1838 in the Iberian Peninsula

Material examined

SPAIN, Gerona: 1♂ and 2♀, Caralps, 1200–1300m, 13–17.vi.1982, Leg.: S. Andersen, V. Michelsen & L. Lyneborg, Det.: A. Vujić 2009 (male identified by Torp in 1986; one female identified by Torp in 1986 as *M. avidus* (Rossi) and by Hurkmans in 1987 as *M. rufus*; one female identified by Torp in 1986 and by Hurkmans in 1987) (ZMUC); 1♀, Ribas de Freser, 21.vii.1970, Det.: A. Vujić 2008; 10 specimens, Setcasas, 3♂ and 2♀, 15.vii.1970, 1♂ and 1♀, 18.vii.1970 (male collected at 1400–1500 m and identified by Van der Goot), 3♂ and 2♀, 20.vii.1970 (one female collected at 1400–1500 m and identified by Van der Goot), Det.: A. Vujić 2008 (ZMA); Teruel: 1♂, Sierra de Albarracín, 25.vii.1979, Leg.: Guerra, Det.: A. Vujić 2008 (ZMA); Orense: Prada, 7.vii.1985, Leg. Veronese, Det.: A. Vujić 2008 (ZMA).

Range

The Netherlands, south to the northern half of Spain, the Mediterranean, and North Africa and east through central and southern Europe into European parts of Russia and on to Kazakhstan.

Additions to the Iberian *Merodon* key

We provide refinements to couplets in the key to Iberian *Merodon* in Marcos-García *et al.* (2007), based on our results and the record of *Merodon distinctus* Palma reported by Ricarte and Marcos-García (2008).

Merodon confusus*, *M. equestris*, and *M. flavus

Males – change couplet 34:

34 Hind tibiae with large central bulge (Figs. 2, 4, 5); male genitalia as in Figs. 12–15, 17; body hairs may range from predominantly pale to wholly black on posterior half of scutum and on tergite III 34*a*

— Bulge on hind tibiae small or absent (Fig. 3); male genitalia as in Fig. 16. . . . . *M. flavus*

34*a* Apical process of hind tibia shorter and not strongly incurved (Fig. 11); cercal triangle lower (bc = 1–1.23) (Figs. 23–27). . . . . *M. confusus*

— Apical process of hind tibia longer and conspicuously incurved (Fig. 10); cercal triangle higher (bc = 0.66–0.96) (Figs. 18–22) . . . . *M. equestris*

Females – change couplet 50:

50 Hind femora with long hairs ventrally (hairs as long as femur width) (Fig. 42); tergites III and IV with long semi-adpressed and erect hairs 50*a*

— Hind femora without such long hairs ventrally; tergites III and IV predominantly with adpressed hairs intermixed with a few erect hairs . . . . *M. flavus*

50*a* Small species (10–12.5 mm); basoflagellomere short (bf = 1.1). . . . . *M. confusus*

— Larger species (13–17 mm); basoflagellomere longer (bf = 1.3) . . . . *M. equestris*

Merodon distinctus

Males – change first step of couplet 5 to lead to 5*a*:

5*a* Short body hairs; scutellar hairs 3× shorter than scutellum length; pale hairs on anterior half of scutum, on an oval to triangular area close to scutellum and on postalar callus; scutum with a band of short adpressed black hairs between wing bases; basoflagellomere short (bf = 1.0) and yellow; tibiae and tarsi wholly pale; surstylus of male genitalia as in Fig. 43.. . . . . *M. distinctus*

5*b* Body hairs longer; longest hairs of scutellum as long as half of scutellum length; scutum with different arrangement of hairs. 6

Females – change first step of couplet 10 to lead to 10*a*:

10*a* Legs wholly yellowish red; body hairs extremely short. . . . . *M. distinctus*

10*b* Legs with at least femora black. 11

Merodon rufus

Males – change second step of couplet 41 to lead to 41*a*:

41*a* Surstylus of male genitalia with extensions between anterior and posterior lobes (Fig. 44); all tergites shiny, without pollinose bands . . . . *M. rufus*

41*b* Surstylus without extensions between anterior and posterior lobes. 43

Females – change first step of couplet 48 to lead to 48*a*:

48*a* Frons shiny, without lateral pollinose markings. . . . . *M. rufus*

48*b* Frons with broad lateral pollinose markings 49

New synonymy

Merodon pumilus **Macquart in Lucas, 1849**

M. pumilus Macquart in Lucas, 1849: 466

M. aeneus fulvus Gil Collado, 1930: 262 **syn. n.**

Marcos-García *et al.* (2007) redefined *M. pumilus* and considered it a valid species. *Merodon aeneus fulvus* was described from a single female; in Gil Collado's collection there is one specimen with its original name label and we accept this specimen as the holotype: female "*fulvus* / Type" (Arenas de San Pedro, Spain) (IEE). Identity: available name, a junior synonym of *M. pumilus*. Comparison between the holotype of *M. aeneus fulvus* and specimens of *M. pumilus* shows that they are conspecific.

Errata

We provide the following corrections to Marcos-García *et al.* (2007): on the first step of couplet 55 on page 539, "trochanter" should be replaced with "femora". When describing the variability of *Merodon chalybeus* Wiedemann (p. 547), "(Figs. 61, 62)" should be replaced with "(Figs. 47, 48)"; "(Figs. 63, 64)" with "(Figs. 51, 52)"; "(Figs. 65–68)" with "(Figs. 53–56)";

Table 1. Range of variability in three different characters of taxa belonging to the *Merodon equestris* species group.

	Size (mm)	bc (male)	bf (female)	m–f
Merodon equestris	13–17	0.66–0.96	1.21–1.28	22–16
Merodon flavus	9–15	1.11–1.47	1.24–1.46	8–4
Merodon confusus	10–12.5	1.00–1.23	1.00–1.12	22–18
"Morphological *M. confusus*"	10–15	1.00–1.25	1.07	10–1
"Intermediate *M. confusus*/*M. equestris*"	13–15	0.93–1.07	1.26	3–0

Note: "Morphological *M. confusus*" refers to specimens morphologically fitting to the type material of *Merodon confusus* but not genetically tested. "Intermediate *M. confusus*/*M. equestris*" refers to specimens with morphology intermediate between *M. confusus* and *M. equestris*. bc, relation between the basal line of cercus and its height; bf, relation between the distance from the basoflagellomere apex and the most prominent point of the pedicel, and the basoflagellomere width at the level of the arista base; m, number of studied males; f, number of studied females.

"(Fig. 65)" with "(Fig. 53)"; and "(Fig. 68)" with "(Fig. 56)". In the description of the male genitalia of *Merodon crypticus* Marcos-García, Vujic and Mengual (p. 551) "(Fig. 154)" should be replaced with "(Fig. 162)". In the diagnosis of *Merodon legionensis* Marcos-García, Vujic and Mengual (p. 559), the first and second citations of "*M. pumilus*" should each be replaced with "*M. unicolor*".

Discussion

All *M. confusus* type specimens were collected in the Cabañeros National Park, central Spain. This protected area has nearly 41 000 ha of Mediterranean ecosystems with an altitudinal range from 520 to 1448 m (Jiménez 2004). *Merodon confusus* is the fourth *Merodon* species described from Cabañeros (Marcos-García *et al.* 2007) and this genus is the most species rich among the hoverflies found there (Ricarte and Marcos-García 2008). Thirteen species of *Merodon* occur in Cabañeros (35% of the Iberian *Merodon* fauna).

Specimens of *M. confusus* were found in some of the primary woodlands of Cabañeros: *F. angustifolia* riparian forests, *Q. pyrenaica* forests, and mixed forests of *F. angustifolia* and *Q. pyrenaica* (Vaquero 1997). However, there were also records in scrublands and open areas within forests. *Merodon confusus* uses open, often stony environments for thermoregulation, but also scrublands and forests because of the presence of potential hosts for larvae (bulbs and tubers of geophytic plants). Species of *Merodon* have close relationships with such plants and co-occur with their hosts in Cabañeros (Ricarte *et al.* 2008). Geophytes are diverse and widespread throughout Cabañeros and this probably explains the high diversity of *Merodon* there. For instance, geophytes are dominant herbaceous plants in the Cabañeros forests (Fernández-González and Pérez-Badía 2004) where species of *Merodon*, including *M. confusus*, are frequently encountered.

Merodon confusus is expected to be widely distributed around the Mediterranean area of the Iberian Peninsula and southeastern France. *Merodon equestris* appears to be restricted to the mountainous Euro-Siberian region of the northern part of the Iberian Peninsula (Fig. 1). There is no evidence of damage to ornamental plant bulbs in Spain and *M. equestris* does not appear to be abundant there (Marcos-García 1990). This scenario could be similar across southwestern Europe, where damage produced by larvae of *M. equestris* to ornamental *Narcissus* bulbs is rare.

It will be important to discover the host plant of *M. confusus* in order to evaluate the economic importance of this hoverfly. Studies such as the present one ensure a precise taxonomic diagnosis of potential pest species; confident identification is of key importance for effective pest-control measures in a given study area. In addition, this study has helped

Table 2. Uncorrected pairwise divergences (%) between specimens in the *Merodon equestris* species group.

	4722	4723	4725	4738	4740	4744	S478	Y032	Y690	Y753	Y834	Y835	Y836	Y837	Y1198
4722 *confusus*	—														
4723 *confusus*	0.43	—													
4725 *confusus*	0.64	0.21	—												
4738 *confusus*	0.43	0.86	1.07	—											
4740 *confusus*	0.43	0.86	1.07	0.00	—										
4744 *confusus*	0.86	0.43	0.64	0.42	0.42	—									
S478 *confusus*	1.51	1.08	1.29	1.27	1.29	0.86	—								
Y32 *equestris*	3.69	3.25	3.46	3.69	3.69	3.24	2.38	—							
Y690 *equestris*	2.83	2.39	2.60	2.83	2.83	2.38	1.51	1.23	—						
Y753 *equestris*	2.85	2.41	2.63	2.40	2.40	1.96	1.53	1.32	0.00	—					
Y834 *equestris*	3.05	2.61	2.82	2.60	2.60	2.17	1.95	1.76	0.44	0.22	—				
Y835 *equestris*	3.05	2.61	2.82	2.82	2.82	2.39	1.96	1.76	0.45	0.43	0.22	—			
Y836 *equestris*	3.05	2.61	2.82	2.60	2.60	2.17	1.95	1.76	0.44	0.22	0.00	0.22	—		
Y837 *equestris*	3.05	2.61	2.82	2.60	2.60	2.17	1.95	1.76	0.44	0.22	0.00	0.22	0.00	—	
Y1198 aff *equestris*	2.17	1.73	1.94	1.73	1.73	1.29	1.08	1.75	1.32	1.08	1.30	1.52	1.30	1.30	—

to determine the biogeographical distribution of the species belonging to the *M. equestris* complex in Europe.

Adult *M. confusus* and *M. equestris* appear to fly at different times in the Iberian Peninsula. Collection evidence suggests that adult *M. confusus* and *M. equestris* fly from March to June and from June to August, respectively. Studies focusing on the life cycle of *M. confusus* and on its relationships with the host plants will help to clarify its geographical distribution and phenology.

Uncorrected interspecific pairwise divergences for species of *Merodon* occurring on Lesvos Island (Greece) ranged from 1.54% between the closely related species *Merodon nigritarsis* Rondani and *Merodon femoratoides* Paramonov to 12.77% between *Merodon erivanicus* Paramonov and *Merodon spinitarsis* Paramonov that are classified in different species groups (Ståhls *et al.* 2009). The Cabañeros National Park specimens of *M. confusus* we sequenced showed different haplotypes, with variability at five nucleotide positions (Fig. 45). We interpret the 5–7 nucleotide differences (1.1%–1.5% divergence) between the Cabañeros specimens and the specimen from Sierra Pozo, Andalucía (Fig. 45, S478), to be an intraspecific difference. Overlap of intra- and interspecific divergence in *Merodon* hoverflies is relatively common (Mengual *et al.* 2006; Milankov *et al.* 2008).

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References

Barkemeyer, W. 1994. Untersuchung zum Vorkommen der Schwebfliegen in Niedersachsen und Bremen (Diptera: Syrphidae). Naturschutz und Landschaftspflege in Niedersachsen, **31**: 1–514.

Bremer, K. 1988. The limits of acmino acid sequence data in angiosperms phylogenetic reconstruction. Evolution, **42**: 795–803. doi:10.2307/2408870.

Bremer, K. 1994. Branch support and tree stability. Cladistics, **10**: 295–304. doi:10.1111/j.1096-0031.1994.tb00179.x.

Conijn, C.G.M. 1990. Control of the large narcissus fly, *Merodon equestris* Fab. (Diptera: Syrphidae) in the field. Mededelingen van de Faculteit Landbouwwetenschappen / Rijksuniversiteit Gent, **55**: 675–679.

Doczkal, D. 1996. Description of two new species of the genus *Eumerus* Meigen (Diptera, Syrphidae) from Corsica. Volucella, **2**: 3–19.

Fernández-González, F., and Pérez-Badía, R. 2004. El Bosque Mediterráneo, Flora y vegetación. *In* La Red de Parques Nacionales de España. *Edited by* Canseco Editores S.L. Organismos Autónomo de Parques Nacionales, Madrid, Spain. pp. 251–271.

Folmer, O., Black, M., Hoeh, W., Lutz, R., and Vrijenhoek, R. 1994. DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology, **3**: 294–299.

Goloboff, P. 1999. NONA vers. 2 [online]. Available from http://www.cladistics.com/aboutNona.htm [accessed 5 January 2001].

Hurkmans, W. 1993. A monograph of *Merodon* (Diptera: Syrphidae). Part 1. Tijdschrift voor Entomologie, **136**: 147–234.

Jiménez, J. 2004. Parque Nacional de Cabañeros. *In* La Red de Parques Nacionales de España. *Edited by* Canseco Editores S.L. Organismos Autónomo de Parques Nacionales, Madrid, Spain. pp. 90–93.

Kimura, M. 1980. A simple method for estimating evolutionary rate of base substitution through comparative studies of nucleotide sequences. Journal of Molecular Evolution, **16**: 111–120. doi:10.1007/BF01731581.

Marcos-García, M.A. 1990. Catálogo preliminar de los Syrphidae (Diptera) de la Cordillera Cantábrica (España). Eos, **66**: 81–235.

Marcos-García, M.A., Vujić, A., and Mengual, X. 2007. Revision of Iberian species of the genus *Merodon* Meigen, 1803 (Diptera: Syrphidae). European Journal of Entomology, **104**: 531–572.

Mengual, X., Ståhls, G., Vujić, A., and Marcos-García, M.A. 2006. Integrative taxonomy of Iberian *Merodon* species (Diptera: Syrphidae). Zootaxa, **1377**: 1–26.

Milankov, V., Ståhls, G., Stamenkovic, J., and Vujić, A. 2008. Genetic diversity of populations of *Merodon aureus* and *M. cinereus* species complexes (Diptera, Syrphidae): integrative taxonomy and implications for conservation priorities on the Balkan Peninsula. Conservation

Genetics, **9**: 1125–1137. doi:10.1007/s10592-007-9426-8.

Nixon, K.C. 2002. Winclada version 1.00.08 [online]. Available from http://www.cladistics.com [accessed 5 January 2003].

Popov, G.V. 2000. A new synonym of *Merodon tricinctus* (Diptera, Syrphidae). Vestnik Zoology, **34**: 99–102.

Radenković, S., Vujić, A., Ståhls, G., Pérez-Bañón, C., Rojo, S., Petanidou, T., and Šimić, S. 2011. Three new cryptic species of the genus *Merodon* Meigen (Diptera: Syrphidae) from the island of Lesvos (Greece). Zootaxa, **2735**: 35–56.

Ricarte, A., and Marcos-García, M.A. 2008. Los sírfidos (Diptera: Syrphidae) del Parque Nacional de Cabañeros (España): una herramienta para la gestión. Boletín de la Asociación española de Entomología, **32**: 19–32.

Ricarte, A., Marcos-García, M.A., and Rotheray, G.E. 2008. The early stages and life histories of three *Eumerus* and two *Merodon* species (Diptera: Syrphidae) from the Mediterranean region. Entomologica Fennica, **19**: 129–141.

Simon, C., Frati, F., Beckenbach, A., Crespi, B., Liu, H., and Flook, P. 1994. Evolution, weighing, and phylogenetic utility of mitochondrial gene sequences and a compilation of conserved polymerase chain reaction primers. Annals of the Entomological Society of America, **87**: 651–701.

Speight, M.C.D. 2010. Species accounts of European Syrphidae (Diptera) 2010. Syrph the Net, the database of European Syrphidae, vol. 59 Syrph the Net publications, Dublin, Ireland.

Ståhls, G., Vujić, A., Pérez-Bañón, C., Rojo, S., Petanidou, T. 2009. COI barcodes for identification of *Merodon* hoverflies (Diptera, Syrphidae) of Lesvos Island (Greece). Molecular Ecology Resources, **9**: 1431–1438. doi:10.1111/j.1755-0998.2009.02592.x.

Thompson, F.C. 1999. A key to the genera of the flower flies of the Neotropical Region with the description of two new genera and eight new species. Contributions on Entomology, International, **3**: 319–378.

Vaquero, J. 1997. Flora vascular y vegetación. *In* Parque Nacional de Cabañeros. *Coordinated by* V. García-Canseco and L. Alonso-Valero. Ecohábitat, Spain. pp. 70–154.